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Studies on the anastomosis groups of *Rhizoctonia solani* Kühn in Taiwan [1]

C. C. Tu and Y. C. Chang [2]

Abstract : Anastomosis among 264 isolates of *Rhizoctonia solani* (=*Thanatephorus cucumeris*) indicated that 251 isolates fell into one of five groups (TRAG 1-TRAG 5) corresponding to groups previously descriebd by Ogoshi in Japan. Four of them (TRAG 1-TRAG 4) were also comparable with those groups reported by Parmeter, et al in the North America, and Schultz and Richter & Schneider in the Europe.

Anastomosis between isolates from the same group was perfect fusion, imperfect fusion, or contact fusion. No hyphal fusion was observed between isolates of different groups. Each anastomosis group seemed to have specificity in the host range, but this specificity was not rigid.

Rhizoctonia solani Kühn is a widespread and destructive soil-borne plant pathogen. It consists of a great number of isolates differing in various characteristics [2]. Several workers [1,3,13,15] had attempted to group *R. solani* by cultural, physiological, morphological, or pathological criteria, but their groupings were finally found to be with only little practical value because of overlapping of these characteristics among groups. Schultz [12] and Richter & Schneider [11] reported that capacity to anastomose provided an indication of relationship within groups of isolates in *R. solani*. Isolates within each of several groups anastomosed with other isolates within the group, but not with isolates from other group. It was also found that there were greater morphologic and physiologic similarities within an anastomosis group than between groups. Unfortunately, the significant value of anastomosis groups of *R. solani* was not commonly recognized and accepted until Parmeter, et al (1969) published an intensive study in 1969.

Anastomosis groups of *R. solani* have been reported from Europe [11,12], North America [9], and Japan [5,6,7,8], but similar report has not been found in Taiwan yet. This report describes the anastomosis groups of *R. solani* in Taiwan and their co-relationship with the groups reported in literature.

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Materials and Methods

Approximately 282 isolates presumed to be *R. solani* were collected. All isolates were examined critically according to current species criteria[10], and 264 of them were confirmed to be *R. solani* (Table 1). All varified isolates of *R. solani* were tested for anastomosis relationships.

Anastomosis was tested by opposing isolates on 2% water agar or on cellophane resting on water agar in petri dishes. Mycelial transfers from the margins of actively expending young cultures on potato-dextrose agar were incubated at room temperature or at 23-26°C until advancing hyphae made contact and slightly overlaped. This portion was then removed, mounted on a slide, stained with cotton blue in diluted lacto-phenol, and was observed under a microscope.

Eighteen isolates from five anastomosis groups in Japan[8] were supplied to the authors by Dr. Akira Ogoshi. Thus, anastomosis between these isolates and the representative isolates of Taiwan were also observed.

Results

Anastomosis reactions. There were various kinds of anastomosis reaction between hyphae of *R. solani*. It might occur between two hyphal tips (Fig. 1), a hyphal tip and a telemorphic branch (Fig. 2C), or two telemorphic branches of very close parallel hyphae(Fig. 2B). In fact, hyphae usually grew across each other without anastomosis even they came from the same isolate.

A successful anastomosis, also called"perfect fusion", involved three steps ; hyphal contact, cell-wall fusion, and cytoplasmic fusion. When two hyphae were close enough, usually in 7—15 μm, their tips inclined towards one another(Fig. 1A) and rapidly made contact (Fig. 1B), then anastomosed after flattening against one another by lysis of the double cell-wall thus formed (Fig. 1C). Consequently cytoplasmic exchange (Fig. 1D) followed. The duration for the completion of this process was approximately 40—60 minutes.

In the course of anastomosis before hyphal contact, one of three cases might occur ; hyphae of two isolates were attracted each other (Fig. 1A), hyphae of one isolate was attracted by hyphae of another isolate (Fig. 2C & F), or such attracting phenomena were not observed and thus, hyphae approched one another by chance. Anastomosis within one and the same isolate was perfect fusion (Fig. 2B), anastomosis between isolates from the same group might be perfect fusion (Fig. 1, and 2A & D), imperfect fusion (Fig. 2E), or contact fusion(Fig. 2F). The imperfect fusion resulted in the death of fused and adjacent cells. The contact fusion showed only hyphal contact without further hyphal growth, cell-wall fusion, and cytoplasmic fusion.

Anastomosis groups. Based on the fact that anastomosis between isolates from the same group was perfect fusion, imperfect fusion, or contact fusion, two isolates formed perfect fusion or imperfect fusion meaned that these two isolates belonged to the same anastomosis group. Thus, 251 out of 264 tested isolates were classified into five anasto-

mosis groups(Table 1). In order to distinguish these groups from those of reported from other countries, they were designated Taiwan *Rhizoctonia solani* Anastomosis Group (TRAG) 1, 2, 3, 4, and 5.

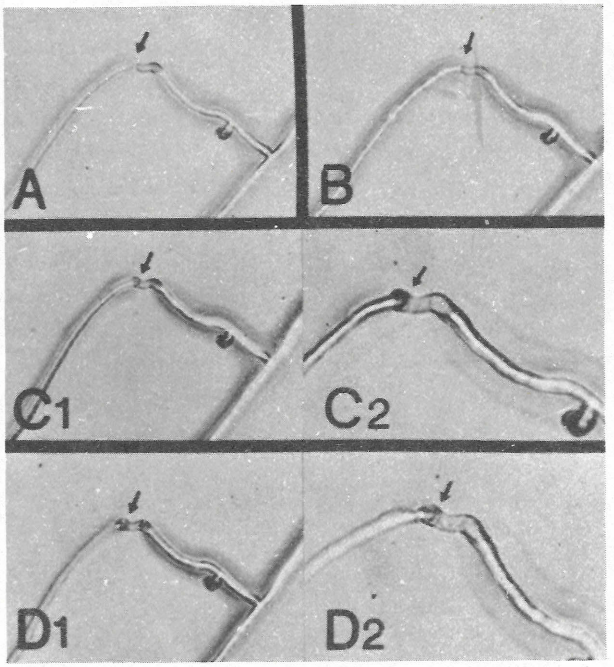

Fig. 1. Hyphal anastomosis between isolates F3 and SW 10. A. Hyphal tips attracting each other. B. Contacting of hyphal tips. C1. & C2. Lysis of contacting cell-wall. D1. & D2. Cytoplasmic exchange of anastomosed cells.

TRAG 1 : This group contained 184 isolates, to which most of them were isolated from rice (*Oryza sativa*). Rest of them were from peanut (*Arachis hypogaea*), soybean (*Glycine max*), sorghum (*Sorghum vulgare*), mungbean (*Vigna radiata*), flax (*Linum usitatissimum*), potato (*Solanum tuberosum*), and soil. The host plants of TRAG 1 distributed in seven genera as listed in Table 2.

TRAG 2 : This group contained 17 isolates. They were from sweet pepper (*Capsicum frulescens*), tulip(*Tulipa gesneriana*), radish (*Raphanus sativus*), Matrush (*Juncus effusus*), flax, potato, and soil.

TRAG 3 : This group contained 9 isolates. All of them were from potatoes, and were isolated from potato tubers only.

TRAG 4 : This group contained 38 isolates. Most of them were from potatoes, and were isolated from both tuber and stem. The host plants of this group included chrysanthemum (*Chrysanthemum cinerariifolium*), jute (*Corchorus capsularis*), watermelon (*Citrulus vulgaris*), kenaf (*Hibiscus cannabinus*), garlic (*Allium scorodoprasum* var. *viviparum*), sweet pepper, potato, flax, and soil.

TRAG 5 : This group contained only 3 isolates, to which one was isolated from soybean root, and another two isolates were from soil.

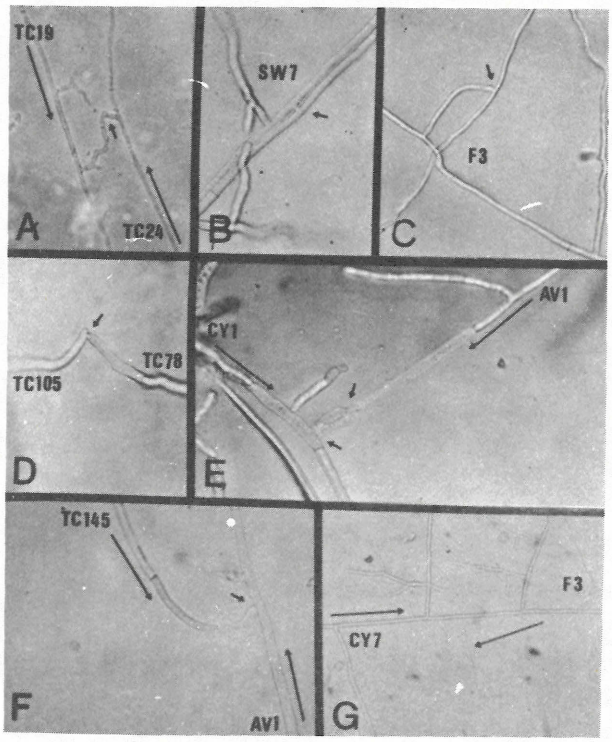

Fig. 2. Various kinds of hyphal anastomosis of *Rhizoctonia solani*. A. Perfect fusion between two isolates (TC 19 and TC 24) from the same anastomosis group. B. & C. Perfect fusion between hyphae of the same isolate. D. & E. Imperfect fusion between isolates (TC 78 and TC 105, CY 1 and AV 1) of the same anastomosis group. F. Contact fusion between solates (TC 145 and AV 1) of the same anastomosis group. G. No hyphal fusion between isolates (CY 7 and F3) of different anastomosis groups.

Thirteen of the 264 isolates could not be assigned to any of the five anastomosis groups. These isolates included those from rice, potato, sweet potato, asparagus, and *Cymbidium* sp.

Comparison of anastomosis groups in Taiwan with groups reported in Japan and other countries. Ogoshi [5,6,7,8] reported five anastomosis groups in Japan. Eighteen isolates of these five anastomosis groups were kindly supplied to the authors from Dr. Ogoshi in 1975. Anastomosis were observed between these 18 isolates and the representative isolates of Taiwan. The results indicated that groups from both countries were comparable (Table 3). In the another words, AG-1, AG-2, AG-3, AG-4, and AG-5 of Japan were identical with TRAG 1, TRAG 2, TRAG 3, TRAG 4. and TRAG 5 of Taiwan. Ogoshi [7] divided AG-2 into two types by the frequency of anastomosis. However, it

Table 1. Source and origin of tested isolates of *Rhizoctonia solani*.

Isolate	Host	Plant part	Locality	Date	Collector*
TRAG 1					
TC 1	*Arachis hypogaea*	Stem	Chia-i	Jun 1967	Y. H. Han
TC 5	*Arachis hypogaea*	Stem	Chia-i	Jun 1967	Y. H. Han
TC 18	*Arachis hypogaea*	Leaf	Chia-i	Jun 1967	Y. H. Han
TC 22	*Glycine max*	Stem	Ping-tung	Sep 1967	Y. H. Han

Table 1. (Continued)

Isolate	Host	Plant part	Locality	Date	Collector[a]
TC 26	*Glycine max*	Stem	Ping-tung	Sep 1967	Y. H. Han
TC 27	*Glycine max*	Stem	Ping-tung	Sep 1967	Y. H. Han
TC 28	*Glycine max*	Leaf	Ping-tung	Sep 1967	Y. H. Han
TC 30	*Glycine max*	Leaf	Ping-tung	Sep 1967	Y. H. Han
TC 32	*Glycine max*	Root	Ping-tung	Sep 1967	Y. H. Han
TC 35	*Glycine max*	Leaf	Ping-tung	Sep 1967	Y. H. Han
TC 36	*Oryza sativa*	Sheath	Tai-chung	May 1967	Y. H. Han
TC 37	*Oryza sativa*	Sheath	Tai-chung	May 1967	Y. H. Han
TC 38	*Oryza sativa*	Sheath	Tai-chung	May 1967	Y. H. Han
TC 40	*Oryza sativa*	Sheath	Tai-chung	May 1967	Y. H. Han
TC 41	*Oryza sativa*	Sheath	Tai-chung	May 1967	Y. H. Han
TC 42	*Oryza sativa*	Sheath	Tai-chung	May 1967	Y. H. Han
TC 43	*Oryza sativa*	Leaf	Tai-chung	May 1967	Y. H. Han
TC 44	*Oryza sativa*	Sheath	How-lii	May 1967	Y. H. Han
TC 45	*Oryza sativa*	Leaf	How-lii	Jul 1967	Y. H. Han
TC 47	*Oryza sativa*	Sheath	Ta-chia	May 1967	Y. H. Han
TC 49	*Oryza sativa*	Sheath	Sha-luh	May 1967	Y. H. Han
TC 50	*Oryza sativa*	Leaf	Ta-chia	May 1967	Y. H. Han
TC 51	*Oryza sativa*	Leaf	Tai-chung	Jun 1967	Y. H. Han
TC 52	*Oryza sativa*	Leaf	Tai-chung	Jun 1967	Y. H. Han
TC 53	*Oryza sativa*	Sheath	Tai-chung	May 1967	Y. H. Han
TC 59	*Oryza sativa*	Sheath	Ta-juanh	Jul 1967	Y. H. Han
TC 62	*Oryza sativa*	Sheath	How-lung	Jul 1967	Y. H. Han
TC 63	*Oryza sativa*	Leaf	How-lung	Jul 1967	Y. H. Han
TC 67	*Oryza sativa*	Sheath	Miau-li	Jul 1967	Y. H. Han
TC 68	*Oryza sativa*	Sheath	Miau-li	Jul 1967	Y. H. Han
TC 69	*Oryza sativa*	Leaf	Miau-li	Jul 1967	Y. H. Han
TC 71	*Oryza sativa*	Leaf	Miau-li	Jul 1967	Y. H. Han
TC 72	*Oryza sativa*	Sheath	Miau-li	Jul 1967	Y. H. Han
TC 75	*Oryza sativa*	Sheath	Shiang-shan	Jul 1967	Y. H. Han
TC 76	*Oryza sativa*	Sheath	Hsin-chu	Jul 1967	Y. H. Han
TC 78	*Oryza sativa*	Sheath	Dood-liu	Sep 1967	Y. H. Han
TC 79	*Oryza sativa*	Sheath	Dood-liu	Sep 1967	Y. H. Han
TC 80	*Oryza sativa*	Leaf	Dood-liu	Sep 1967	Y. H. Han

Table 1. (Continued)

Isolate	Host	Plant part	Locality	Date	Collector[a]
TC 81	*Oryza sativa*	Leaf	Dood-liu	Sep 1967	Y. H. Han
TC 82	*Oryza sativa*	Sheath	Tsyh-torng	Sep 1967	Y. H. Han
TC 87	*Oryza sativa*	Sheath	Lii-goang	Sep 1967	Y. H. Han
TC 88	*Oryza sativa*	Sheath	Dood-nan	Sep 1967	Y. H. Han
TC 89	*Oryza sativa*	Sheath	Tai-dong	Sep 1967	Y. H. Han
TC 90	*Oryza sativa*	Sheath	Tai-dong	Sep 1967	Y. H. Han
TC 91	*Oryza sativa*	Sheath	Tai-dong	Sep 1967	Y. H. Han
TC 92	*Oryza sativa*	Leaf	Tai-dong	Sep 1967	Y. H. Han
TC 95	*Oryza sativa*	Leaf	Tai-dong	Sep 1967	Y. H. Han
TC 96	*Oryza sativa*	Sheath	Shin-ying	Sep 1967	Y. H. Han
TC 97	*Oryza sativa*	Sheath	Shin-ying	Sep 1967	Y. H. Han
TC 99	*Oryza sativa*	Sheath	Nan-tour	Sep 1967	Y. H. Han
TC 100	*Oryza sativa*	Sheath	Keng-kou	Sep 1967	Y. H. Han
TC 101	*Oryza sativa*	Sheath	Keng-kou	Sep 1967	Y. H. Han
TC 102	*Oryza sativa*	Sheath	Keng-kou	Sep 1967	Y. H. Han
TC 103	*Oryza sativa*	Sheath	Chye-dong	Sep 1967	Y. H. Han
TC 104	*Oryza sativa*	Sheath	Chang-chun	Sep 1967	Y. H. Han
TC 105	*Oryza sativa*	Sheath	Yang-mei	Sep 1967	Y. H. Han
TC 106	*Oryza sativa*	Sheath	Shin-juang	Sep 1967	Y. H. Han
TC 107	*Oryza sativa*	Sheath	Chang-chun	Sep 1967	Y. H. Han
TC 108	*Oryza sativa*	Sheath	Miau-li	Sep 1967	Y. H. Han
TC 109	*Oryza sativa*	Sheath	San-i	Sep 1967	Y. H. Han
TC 110	*Oryza sativa*	Sheath	San-i	Sep 1967	Y. H. Han
TC 111	*Oryza sativa*	Leaf	San-i	Sep 1967	Y. H. Han
TC 112	*Oryza sativa*	Sheath	Jiau-shi	Sep 1967	Y. H. Han
TC 113	*Oryza sativa*	Sheath	Jiau-shi	Sep 1967	Y. H. Han
TC 115	*Oryza sativa*	Sheath	Yi-lan	Sep 1967	Y. H. Han
TC 116	*Oryza sativa*	Sheath	Low-dong	Sep 1967	Y. H. Han
TC 117	*Oryza sativa*	Sheath	Yi-lan	Sep 1967	Y. H. Han
TC 118	*Oryza sativa*	Sheath	Yi-lan	Sep 1967	Y. H. Han
TC 119	*Oryza sativa*	Leaf	Yi-lan	Sep 1967	Y. H. Han
TC 120	*Graminaceae*	Sheath	Yi-lan	Sep 1967	Y. H. Han
TC 121	*Graminaceae*	Sheath	Chung-lun	Sep 1967	Y. H. Han
TC 123	*Oryza sativa*	Sheath	Erh-cheng	Sep 1967	Y. H. Han

Table 1. (Continued)

Isolate	Host	Plant part	Locality	Date	Collector[a]
TC 125	*Oryza sativa*	Sheath	Long-tyan	Sep 1967	Y. H. Han
TC 126	*Oryza sativa*	Sheath	Tou-cheng	Sep 1967	Y. H. Han
TC 128	*Oryza sativa*	Sheath	Ta-lii	Sep 1967	Y. H. Han
TC 130	*Oryza sativa*	Sheath	Yi-lan	Sep 1967	Y. H. Han
TC 132	*Oryza sativa*	Sheath	Yi-lan	Sep 1967	Y. H. Han
TC 136	*Oryza sativa*	Sheath	Tai-chung	Sep 1967	Y. H. Han
TC 138	*Oryza sativa*	Sheath	Sha-luh	Sep 1967	Y. H. Han
TC 140	*Oryza sativa*	Sheath	Ta-chia	Jul 1967	Y. H. Han
TC 141	*Oryza sativa*	Sheath	Ta-juang	Jul 1967	Y. H. Han
TC 142	*Oryza sativa*	Sheath	How-lii	Jul 1967	Y. H. Han
TC 145	*Oryza sativa*	Sheath	Shin-chu	Jul 1967	Y. H. Han
TC 147	*Oryza sativa*	Sheath	Dood-liu	Jul 1967	Y. H. Han
TC 148	*Oryza sativa*	Sheath	Kao-hsiung	Jul 1967	Y. H. Han
TC 150	*Oryza sativa*	Sheath	Ping-tung	Jul 1967	Y. H. Han
TC 151	*Oryza sativa*	Sheath	Ching-choei	Jul 1967	Y. H. Han
TC 155	*Oryza sativa*	Sheath	San-i	Jul 1967	Y. H. Han
TC 156	*Oryza sativa*	Sheath	Shin-chu	Jul 1967	Y. H. Han
TC 157	*Oryza sativa*	Sheath	Wai-macao	Jul 1967	Y. H. Han
TC 158	*Oryza sativa*	Sheath	Yi-lan	Jul 1967	Y. H. Han
TC 159	*Oryza sativa*	Sheath	Yi-lan	Jul 1967	Y. H. Han
TC 161	*Oryza sativa*	Sheath	Dan-feng	Jul 1967	Y. H. Han
TC 162	*Oryza sativa*	Sheath	Jiau-shi	Jul 1967	Y. H. Han
CY 1	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 4	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 5	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 6	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 7	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 8	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 9	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 10	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 11	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 12	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 13	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 14	*Oryza sativa*	Sheath	—	—	W. H, Tsai

Table 1. (Continued)

Isolate	Host	Plant part	Locality	Date	Collector[a]
CY 15	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 16	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 17	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 18	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 19	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 20	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 21	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 22	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 23	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 24	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 25	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 26	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 27	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 28	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 30	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 31	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 32	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 33	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 34	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 35	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 36	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 37	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 38	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 40	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 41	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 42	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 43	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 44	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 45	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 46	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 47	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 49	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 50	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 51	*Oryza sativa*	Sheath	—	—	W. H. Tsai

Table 1. (Continued)

Isolate	Host	Plant part	Locality	Date	Collector[a]
CY 52	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 53	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 54	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 55	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 56	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 58	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 59	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 60	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 61	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 62	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 63	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 64	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 65	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 67	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 68	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 69	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 70	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 71	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 72	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 73	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 74	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 75	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 76	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 77	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 78	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 80	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 82	*Oryza sativa*	Sheath	—	—	W. H. Tsai
CY 83	*Oryza sativa*	Sheath	—	—	W. H. Tsai
R 1	*Sorghum vulgare*	Sheath	Tai-chung	—	
R 2	*Sorghum vulgare*	Sheath	Tai-chung	—	
R 3	*Sorghum vulgare*	Sheath	Tai-chung	—	
AV 1	*Vigna radiata*	Leaf	Jang-huah	1975	Y. D. Yang
AV 2	*Vigna radiata*	Leaf	Jang-huah	1975	Y. D. Yang
AV 3	*Vigna radiata*	Leaf	Jang-huah	1975	Y. D. Yang

Table 1. (Continud)

Isolate	Host	Plant part	Locality	Date	Collector[a]
R I 1	*Oryza sativa*	Sheath	Ping-tung	Jun 1975	C. C. Tu
R I 2	*Oryza sativa*	Sheath	Tai-pei	Oct 1975	C. C. Tu
F 5	*Linum usitatissimum*	Stem	Jang-huah	Jan 1977	Y. C. Chang
F 6	*Linum usitatissimum*	Stem	Jang-huah	Jan 1977	Y. C. Chang
F 7	*Linum usitatissimum*	Stem	Jang-huah	Jan 1977	Y. C. Chang
S 1	*Solanum tuberosum*	Tuber	—	—	S. M. Chan
S 53	*Solanum tuberosum*	Tuber	Feng-yuan	Dec 1976	Y. C. Chang
S 59	*Solanum tuberosum*	Tuber	Feng-yuan	Dec 1976	Y. C. Chang
S 60	*Solanum tuberosum*	Tuber	Feng-yuan	Dec 1976	Y. C. Chang
S 110	*Solanum tuberosum*	Tuber	Feng-yuan	Dec 1976	Y. C. Chang
SO 4	Soil		Tai-nan	Sep 1974	C. C. Tu,
TRAG 2					
SW 1	*Capsicum frulescens*	Stem	Nan-jou	Dec 1976	Y. C. Chang
SW 10	*Capsicum frulescens*	Stem	Nan-jou	Dec 1977	Y. C. Chang
F 2	*Linum usitatissimum*	Stem	Tsao-tun	Dec 1976	Y. C. Chang
F 3	*Linum usitatissimum*	Stem	Tsao-tun	Dec 1976	Y. C. Chang
F 4	*Linum usitatissimum*	Stem	Tsao-tun	Dec 1976	Y. C. Chang
S 9	*Solanum tuberosum*	Tuber	How-lii	Dec 1976	Y. C. Chang
S 17	*Solanum tuberosum*	Stem	Feng-yuan	Jan 1977	Y. C. Chang
S 19	*Solanum tuberosum*	Stem	Feng-yuan	Jan 1977	Y. C. Chang
S 20	*Solanum tuberosum*	Stem	Feng-yuan	Jan 1977	Y. C. Chang
S 106	*Solanum tuberosum*	Tuber	How-lii	Jan 1977	H. K. Hsu
S 142	*Solanum tuberosum*	Tuber	How-lii	Jan 1977	H. K. Hsu
TU 1	*Tulipa gesneriana*	Stem	Tai-nan	Feb 1969	C. C. Tu
RA 1	*Raphanus sativus*	Bulb root	Tai-nan	Dec 1971	C. C. Tu
MA 1	*Juncus effusus*	Stem	Chia-i	Jul 1975	C. C. Tu
SO 1	Soil		Tai-chung	Dec 1974	C. C. Tu
SO 6	Soil		Lin-bian	Aug 1976	C. C. Tu
SO 7	Soil		Shin-chu	Dec 1976	C. C. Tu
TRAG 3					
S	*Solanum tuberosum*	Tuber	—	—	S. M. Chen
S 3	*Solanum tuberosum*	Tuber	Feng-yuan	Jan 1976	H. K. Hsu
S 101	*Solanum tuberosum*	Tuber	Feng-yuan	Feb 1977	C. C. Tu
S 102	*Solanum tuberosum*	Tuber	Feng-yuan	Jan 1977	C. C. Tu

Table 1. (Continued)

Isolate	Host	Plant part	Locality	Date	Collector[a]
S 103	*Solanum tuberosum*	Tuber	Feng-yuan	Jan 1977	C. C. Tu
S 124	*Solanum tuberosum*	Tuber	Feng-yuan	Feb 1977	H. K. Hsu
S 129	*Solanum tuberosum*	Tuber	Feng-yuan	Feb 1977	H. K. Hsu
S 134	*Solanum tuberosum*	Tuber	How-lii	Feb 1977	H. K. Hsu
S 138	*Solanum tuberosum*	Tuber	How-lii	Feb 1977	H. K. Hsu
TRAG 4					
C 1	*Chrysanthemum cinerariifoliun*	Stem	Tyan-wei	Sep 1975	S. P Y. Hsieh
J 1	*Corchorus capsularis*	Stem	Guei-jen	Apr 1974	C. C. Tu
W 1	*Citrullus vulgaris*	Stem	Tai-nan	Oct 1975	C. C. Tu
W 2	*Citrullus vulgaris*	Stem	Tai-chung	Sep 1975	J. W. Hwang
TC 6	*Hibiscus cannabinus*	Stem	Tai-chung	May 1974	C. C. Tu
SW 4	*Capsicum frulescens*	Stem	Nan-tour	Jun 1976	K. F. Chang
SW 5	*Capsicum frulescens*	Stem	Nan-tour	Jun 1976	K. F. Chang
SW 6	*Capsicum frulescens*	Stem	Nan-tour	Jun 1976	K. F. Chang
SW 7	*Capsicum frulescens*	Stem	Nan-tour	Jun 1976	K. F. Chang
S 6	*Solanum tuberosum*	Stem	How-lii	Dec 1976	Y. C. Chang
S 7	*Solanum tuberosum*	Stem	How-lii	Dec 1976	Y. C. Chang
S 8	*Solanum tuberosum*	Stem	How-lii	Dec 1976	Y. C. Chang
S 10	*Solanum tuberosum*	Stem	How-lii	Dec 1976	Y. C. Chang
S 11	*Solanum tuberosum*	Stem	How-lii	Dec 1976	Y. C. Chang
S 13	*Solanum tuberosum*	Stem	How-lii	Dec 1976	Y. C. Chang
S 31	*Solanum tuberosum*	Stem	How-lii	Feb 1976	Y. C. Chang
S 32	*Solanum tuberosum*	Stem	How-lii	Feb 1976	Y. C. Chang
S 35	*Solanum tuberosum*	Stem	How-lii	Feb 1976	Y. C. Chang
S 36	*Solanum tuberosum*	Stem	How-lii	Feb 1976	Y. C. Chang
S 37	*Solanum tuberosum*	Tuber	How-lii	Feb 1976	Y. C. Chang
S 38	*Solanum tuberosum*	Stem	How-lii	Feb 1976	Y. C. Chang
S 41	*Solanum tuberosum*	Tuber	How-lii	Feb 1976	Y. C. Chang
G 1	*Allium scorodoprasum* var. *viviparum*	Root	Tai-pei	Apr 1976	Y. C. Chang
S 42	*Solanum tuberosum*	Stem	How-lii	Feb 1977	Y. C. Chang
S 44	*Solanum tuberosum*	Stem	How-lii	Feb 1977	Y. C. Chang
S 107	*Solanum tuberosum*	Stem	Feng-yuan	Jan 1977	H. K. Hsu

Table 1. (Continud)

Isolate	Host	Plnt part	Locality	Date	Collector[a]
S 108	*Solanum tuberosum*	Stem	Feng-yuan	Jan 1977	H. K. Hsu
S 109	*Solanum tuberosum*	Stem	Feng-yuan	Jan 1977	H. K. Hsu
S 110	*Solanum tuberosum*	Stem	Feng-yuan	Jan 1977	H. K. Hsu
S 113	*Solanum tuberosum*	Stem	Feng-yuan	Feb 1977	H. K. Hsu
S 116	*Solanum tuberosum*	Stem	Feng-yuan	Feb 1977	H. K. Hsu
S 118	*Solanum tuberosum*	Stem	Feng-yuan	Feb 1977	H. K. Hsu
S 119	*Solanum tuberosum*	Tuber	Feng-yuan	Feb 1977	H. K. Hsu
S 120	*Solanum tuberosum*	Tuber	Feng-yuan	Feb 1977	H. K. Hsu
S 122	*Solanum tuberosum*	Tuber	Feng-yuan	Feb 1977	H. K. Hsu
F 8	*Linum usitatissimum*	Stem	Jang-huah	Feb 1977	C. C. Tu
SO 2	Soil		Tai-pei	Feb 1975	C. C. Tu
SO 8	Soil		Kao-hsiung	Dec 1976	C. C. Tu
TRAG 5					
SB 1	*Glycine max*	Root	Ping-tung	Nov 1976	C. C. Tu
SO 3	Soil		Tai-pei	May 1976	C. C. Tu
SO 5	Soil		Tai-pei	Sep 1976	C. C. Tu
Not Grouped					
TC 48	*Oryza sativa*	Sheath	Sha-luh	Jun 1967	Y. H. Han
TC 85	*Oryza sativa*	Sheath	Choei-shang	Sep 1967	Y. H. Han
TC 94	*Oryza sativa*	Sheath	Fu-lii	Sep 1967	Y. H. Han
TC 131	*Oryza sativa*	Sheath	Yi-lan	Sep 1967	Y. H. Han
O 1	*Cymbidium* sp.	Root	Tai-chung	—	S. P. Y. Hsieh
S 25	*Solanum tuberosum*	Stem	How-lii	Jan 1977	Y. C. Chang
SW 2	*Capsicum frulescens*	Stem	Nan-jou	Dec 1976	Y. C. Chang
SW 3	*Capsicum frulescens*	Stem	Nan-jou	Dec 1976	Y. C. Chang
A 1	*Asparagus officinalis*	Stem	Po-tzu	Jun 1975	K. F. Chang
A 2	*Asparagus officinalis*	Stem	Po-tzu	Jun 1975	K. F. Chang
A 3	*Asparagus officinalis*	Stem	Po-tzu	Jun 1975	K. F. Chang
A 4	*Asparagus officinalis*	Stem	Po-tzu	Jun 1975	K. F. Chang
A 5	*Asparagus officinalis*	Stem	Po-tzu	Jun 1975	K. F. Chang

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C. C. Tu, Y. C. Chang, and K. F. Chang (Taiwan Agricultural Research Institute).

Table 2. The host plants (genus) or origins of each anastomosis group of *Rhizoctonia solani* Kühn.

Anastomosis group	Parmeter, et al (1969)	Ogoshi (1976)	Tu & Chang
TRAG 1	*Brassica*	*Acacia*	*Arachis* (Leguminosae)
	Companula	*Beta*	*Glycine* (Leguminosae)
	Ficus	*Brassica*	*Linum* (Linaceae)
	Hydrangea	*Chrysanthemum*	*Oryza* (Graminaceae)
	Lespedeza	*Glycine*	*Solanum* (Solanaceae)
	Oryza	*Hydrosme*	*Sorghum* (Graminaceae)
	Phaseolus	*Hyoscyamus*	*Vigna* (Leguminosae)
	Pinus	*Ipomaea*	soil
		Oryza	
		Phaseolus	
		Raphanus	
		Rhynchosia	
		Solanum	
		Triticum	
		soil	
TRAG 2	*Beta*	*Beta*	*Capsicum* (Solanaceae)
	Brassica	*Brassica*	*Juncus* (Juncaceae)
	Lycopersicum	*Conioselinum*	*Linum* (Linaceae)
	Melilotus	*Daucu*	*Raphanus* (*Cruciferae*)
	Phaseolus	*Fragaria*	*Solanum* (Solanaceae)
	soil	*Hordeums*	*Tulipa* (Liliaceae)
		Linum	soil
		Oryza	
		Raphanus	
		Scirpus	
		Sorghum	
		Tulipa	
		soil	
TRAG 3	*Phaseolus*	*Solanum*	*Solanum* (Solanaceae)
	Solanum		
	soil		

Table 2. (Continued)

Anastomosis group	Parmeter, et al (1969)	Ogoshi (1976)	Tu & Chang
TRAG 4	*Anomas*	*Arachis*	*Allium* (Lilicaceae)
	Beta	*Beta*	*Capsicum* (Solanaceae)
	Cedrus	*Brassica*	*Chrysanthemum* (Compositae)
	Citrus	*Capsicum*	*Citrullus* (Cucurbitaceae)
	Gossypium	*Chrysanthemum*	*Corchorus* (Tiliaceae)
	Gramineae	*Glycine*	*Hibiscus* (Malvaceae)
	Medicago	*Hydrosme*	*Linum* (Linaceae)
	Phaseolus	*Linum*	*Solanum* (Solanaceae)
	Pinus	*Phaseolus*	soil
		Raphanus	
		Spinacia	
		Solanum	
		Trifolium	
		Vigna	
		soil	
TRAG 5		*Arctium*	*Glycine* (Leguminosae)
		Asparagus	soil
		Beta	
		Brassica	
		Glycine	
		Linum	
		Solanum	
		soil	

was true that some isolates of TRAG 2 did only anastomose with isolates of AG-2 Type 1, and some isolates did only anastomose with Type 2, but we also found that some isolates did anastomose with both types (Table 3). Thus, it was considered that further division of TRAG 2 into two types was improper at the present time in Taiwan.

Ogoshi [7] compared his five anastomosis groups with 12 representative isolates of four anastomosis groups of Parmeter, et al [9]. He [7] concluded that AG-1, AG-2, AG -3, and AG-4 of Parmeter, et al were identical with AG-1, AG-2, AG-3, and AG-4 of Japan. After a careful review of literature, we agreed with Ogoshi [7] that AG-1, AG-2, AG-3, and AG-4 of Japan corresponded with I, II, III, and IV of Schultz [12],

Table 3. Anastomosis between TRAG 1-TRAG 5 in Taiwan and AG-1-AG-5 of Ogoshi.

Ogoshi / Tu & Chang	AG-1			AG-2 Type 1			AG-2 Type 2			AG-3			AG-4			AG-5		
	R1-2-1	R1-2-2	A-10	No. 6	CC 519-18	R-21	No. 64	R1-2-6	C-112	P-5	P-9	P-11	R1-2-5	F-14	OH 1010-30	GM-13	KF 722-20	AL-1
TRAG 1																		
SO-4	++	++	++															
RI-1	++	++	++															
RI-2	++	++	++															
CY-7	++	++	++															
TC-132	++	++	++															
TRAG 2																		
SO-6				++	++	++	−	−	−									
SO-7				−	−	−	++	++	++									
MR-1				−	−	−	++	++	++									
S-9				−	++	++	++	++	++									
F-2				+	++	+	++	+	+									
TRAG 3																		
S-101										++	++	++						
S-102										++	++	++						
S-103										++	++	++						
S-2										++	++	++						
S-3										+	++	++						
TRAG 4																		
SO-8													++	++	++			
F-8													++	++	++			
SO-2													++	++	++			
C-1													++	++	++			
J-1													++	++	++			
TRAG 5																		
SB-1																++	++	++
SO-3																++	++	++
SO-5																++	++	++

− : Anastomosis was not observed.
+ : Anastomosis was observed but only 1-2 points in all microscopic field of vision.
++ : Anastomosis was observed very frequently.

Table 4. Comparison of five anastomosis groups of *Rhizoctonia solani* in Taiwan with the groups in several reports.

Tu & Chang (1978)	Schultz (1936)	Richter & Schneider (1953)	Parmeter et al. (1969)	Ogoshi (1976)	Watanabe & Matsuda (1966)
TRAG 1	I (var. *hortensis*)	A	AG-1	AG-1	Sasakii type (IA) Web-blight type (IB)
TRAG 2	II (var. *brassicae*)	D (Crucifer group)	AG-2	AG-2 Type-1 AG-2 Type-2	Winter crop type (II) Rush type (IIIB) Root rot type (IV)
TRAG 3	III (var. *typica*)	E (Potato group)	AG-3	AG-3	Potato type (IV)
TRAG 4	IV (var. *cichorii endiviae*)	G	AG-4	AG-4	Praticola type (IIIA)
TRAG 5		B? *a*		AG-5	

a. not certain, a further test is needed.

A, D, F, and C of Richter & Schneider [11]. He [7] also pointed out that his AG-1, AG-2 Type 1, AG-2 Type 2, AG-3, and AG-4 corresponded with sasakii type and webblight type, winter crop type, rush type and root rot type, potato type, and praticola type of Watanabe & Matsuda [15], respectively.

Parmeter, et al [9] did not find the fifth group as AG-5 by Ogoshi [7] and TRAG 5 by the authors. Ogoshi [7] postulated that his AG-5 perhaps corresponded with B group of Richter & Schneider [11]. Since Ogoshi [7] did not make anastomosis test between these two groups of fungi, this test should be done in future to confirm this postulation. A comparison of five anastomosis groups of *R. solani* in Taiwan with the groups reported in literature was shown in Table 4.

Discussion

It is clear that anastomosis behaviour of *R. solani* is genetically controlled [7,9]. Anastomosis occurs only among isolates of the same group, and not among isolates from different groups. Tu, et al [14] also reported that anastomosis character of an isolate could not be altered with the changes of culture medium, growth temperature, and any other environmental conditions. This fact implies that each anastomosis group is genetically independent.

Many workers, including Schultz [12], Richter & Schneider [11], Parmeter, et al [9], and Ogoshi [5], were unable to place some isolates into any of their groups. The authors also met the same problem. The reason for the failure to assign some isoltes into presently known anastomosis groups has been discussed by Parmeter, et al [9]. However, this failure does not reduce the importance and significance of anastomosis groups of *R. solani*. As pointed out by Ogoshi [7], each anastomosis group has its specific morphological feature and they are easily distinguishable. Parmeter, et al [9] reported that each anastomosis group has its general tendencies on host range and pathogenicity. Schultz [12], Richter & Schneider [11], and Watanabe & Matsuda [15] also have the similar reports.

Anastomosis has also been used as a tool to identify fungal species by mycologists [4]. Some research workers considered that each anastomosis group belonged to a seperate and distinct species. The authors agreed with Ogoshi [7] that this idea seemed not to be appropriate from the standpoint of plant pathology, because there are many examples that more than two anastomosis groups of *R. solani* caused a disease of one host plant. Thus, it was unreasonable to attribute one disease to several different species of pathogen. Nevertheless, we emphasized that all of the diseases already described should be re-assessed and the anastomosis groups of their causal fungus must be identified.

The isolates of *R. solani* in Taiwan were presently classified into five anastomosis groups, namely TRAG 1, TRAG 2, TRAG 3, TRAG 4, and TRAG 5. As indicated in this report and the evidence in the literature, these groups corresponded with AG-1, AG-2, AG-3, AG-4, and AG-5 of Ogoshi [5,6,7,8]. The former four groups also corresponded with AG-1, AG-2, AG-3, and AG-4 of Parmeter, et al [9], I, II, III, and IV of Schultz [12], and A, D, F, and C of Richter & Schneider [10]. Ogoshi [7] further divided his AG-2

into two types. The authors were unable to do so because intermediate isolates of these two types were discovered in Taiwan.

Since there were still some isolates unable to assign into any presently known anastomosis group, the anastomosis groups of *R. solani* in Taiwan described herein were therefore considered tentative. More isolates from different host plants, localities, and seasons are needed for the future studies.

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臺灣 *Rhizoctonia solani* Kühn 菌絲融合羣之研究[1]

杜金池 張義璋[2]

摘 要

Rhizoctonia solani Kühn 菌絲融合 (Anastomosis) 之方式有三：（1）菌絲尖端對菌絲尖端、（2）菌絲尖端對側生小枝 (Telemorphic branch) 及（3）側生小枝對側生小枝等。依融合程度又可分成三種不同結果：（1）完全融合 (Perfect fusion)。（2）不完全融合 (Imperfect fusion) 及（3）接觸融合 (Contact fusion) 等。菌絲完全融合之進行過程先由兩菌絲在相距 7—15μm 處，因相互間或其中一方之吸引而迅速接近，並在40～60分鐘內完成菌絲接觸、細胞壁融合及細胞質融合交流等步驟。完全融合後細胞不會死亡。不完全融合則在細胞質融合後，該細胞或其鄰近細胞會迅速地死亡。接觸融合則只進行到菌絲接觸，並不進行細胞壁及細胞質融合，菌絲亦停止生長。雖很多菌絲在融合前有誘引現象，但亦有許多菌絲並無互相誘引之跡象，菌絲融合完全憑相對菌絲之相遇機率行之。

基於同一菌羣中之兩菌株會發生完全融合、不完全融合、或接觸融合，而不同菌羣之兩菌株間則不發生融合之原理，本省採集之 264 *R. solani* 菌株中，有251菌株可歸類成 TRAG 1、TRAG 2、TRAG 3、TRAG 4 及 TRAG 5 等 5 個菌絲融合羣。另13菌株因互不產生融合，而尚未歸羣。各菌絲融合羣可寄生於不同作物上，而同一作物亦可受不同菌羣寄生。TRAG 1 之寄主植物有花生屬 (*Arachis* sp.)、黃大豆屬 (*Glycine* sp.)、亞麻屬 (*Linum* sp.)、稻屬 (*Oryza* sp.)、茄屬 (*Solanum* sp.)、蜀黍屬 (*Sorghum* sp.) 及豇豆屬 (*Vigna* sp.) 等 7 屬；TRAG 2 之寄主有番椒屬 (*Capsicum* sp.)、燈心草屬 (*Juncus* sp.)、亞麻屬 (*Linum* sp.)、萊菔屬 (*Raphanus* sp.)、茄屬 (*Solanum* sp.) 及鬱金香屬 (*Tulipa* sp.) 等 6 屬；TRAG 3 則只在茄屬 (*Solanum* sp.) 發現；TRAG 4 之寄主範圍爲青葱屬 (*Allium* sp.)、番椒屬 (*Capsicum* sp.)、菊屬 (*Chrysanthemum* sp)、西瓜屬 (*Citrullus* sp.)、黃麻屬 (*Corchorus* sp.)、木槿屬 (*Hibiscus* sp.)、亞麻屬 (*Linum* sp.) 及茄屬 (*Solanum* sp.) 等 8 屬；TRAG 5 目前只在黃大豆屬 (*Glycine* sp.) 分離到。

以臺灣 *R. solani* 5 個菌絲融合羣之代表菌株與分讓自日本 Ogoshi 之 5 個菌絲融合羣代表菌株進行菌絲融合比較試驗。結果證明臺灣之 TRAG 1, TRAG 2, TRAG 3, TRAG 4 及 TRAG 5 依序相當於 Ogoshi (1975) 之 AG-1, AG-2, AG-3, AG-4 及 AG-5。因 Ogoshi (1975) 曾用 Parmeter, et al (1969) 發表之代表菌株進行菌絲融合比較，因此類推前面 4 羣與 Parmeter, et al (1969) 之 AG-1, AG-2, AG-3 及 AG-4, Schultz (1936) 之 I、II、III及IV，以及 Richter 和 Schneider (1953) 之 A. D. F 及 C 菌絲融合羣相當。Ogoshi (1965b) 並指出AG-1, AG-2 type 1, AG-2 type 2, AG-3 及 AG-4 依序相當於 Watanabe 和 Matsuda 之 Sasakii type 和 Web-blight type, Winter crop type, Rush type 和 Root rot type, Potato type 及 Praticola type 等。雖然日本 Ogoshi (1965b) 將 AG-2 分成 type 1 及 type 2 兩型，但因爲本省有中間型菌株，故再分型似有商榷之必要。TRAG 5 (AG 5) 只在日本及臺灣發現，而且 Ogoshi (1975b) 推測與 Richter 和 Schneider (1956) 之 B 羣相當，但因尚未進行菌絲融合試驗，難能眞切確定。

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